Frequency vs Current

Mark Schulist

2022-12-06

Capacitor

I expect that the current will be greater at higher frequencies since capacitors only pass signals, and there are more signals at higher frequencies.

The current increased with frequency. There is a directly proportional relationship between current and frequency with a capacitor.

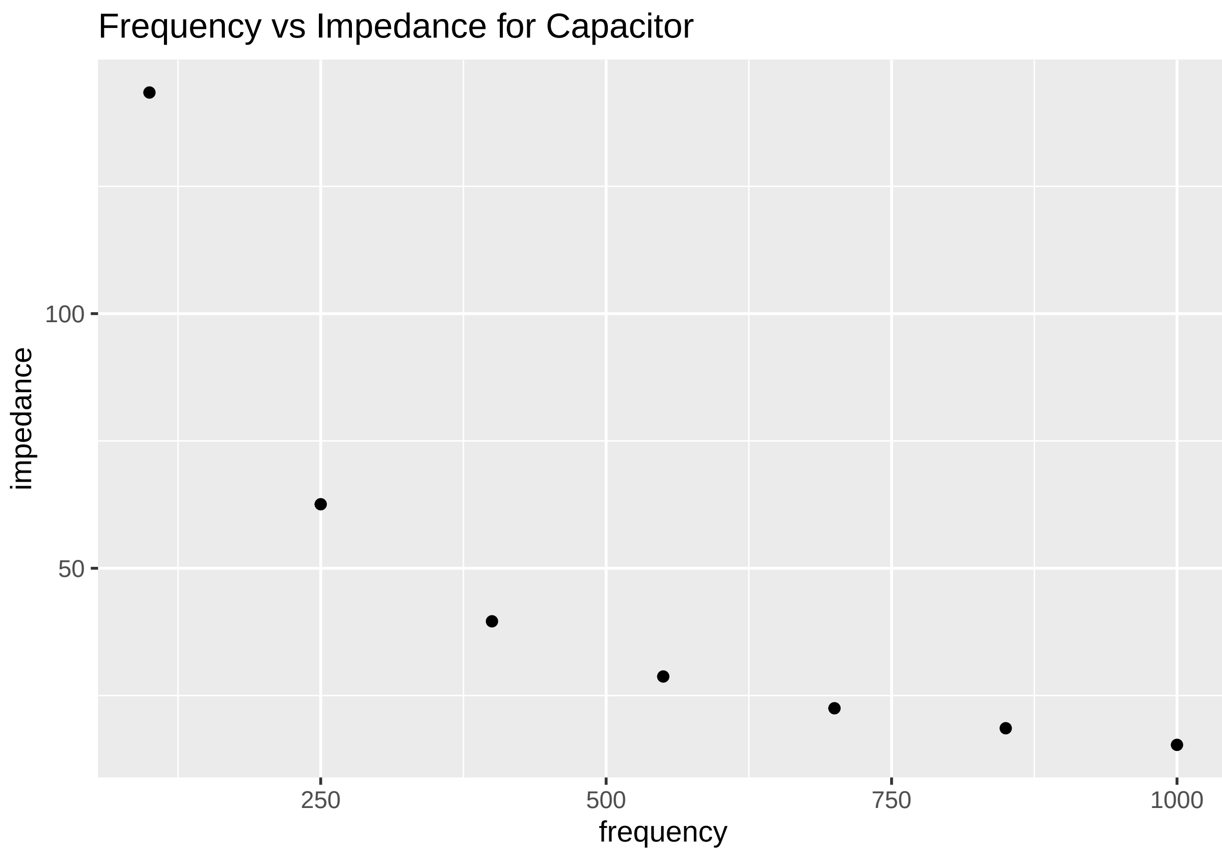
$$\begin{aligned}
X_c &= \frac{1}{2\pi f C} \quad (1) \\
&= \frac{[s]}{[F]} \quad (2) \\
&= \frac{[s][V]}{[C]} \quad (3) \\
&= \frac{[V]}{[A]} \quad (4)
\end{aligned}$$

There is an inverse relationship between capacitive reactance and frequency.

```
capacitor <- read_csv(here("EECS/frequency_vs_current/input/RLC-capacitor.csv"),
                      show_col_types = F)[1:201, ]
# Splitting the df into many dfs for every 3 columns
cap_dfs <- map(
  seq(1, ncol(capacitor), by = 3),
  ~ capacitor[, .x:(.x + 2)]
)
# Getting the frequency as a column
cap_df <- map_df(
  1:length(cap_dfs),
  ~ cap_dfs[[.x]] %>%
    mutate(frequency = parse_number(colnames(cap_dfs[[.x]][1]))) %>%
    rename(time = 1, current = 2, potential = 3)
)
# Summarizing
cap_summary <- cap_df %>%
  group_by(frequency) %>%
  summarize(max(abs(potential)) / max(abs(current))) %>%
  rename(impedance = 2)
```

Now we can graph the frequency vs impedance of the capacitor.

```r
# Graphing
ggplot(cap_summary, aes(frequency, impedance)) +
  geom_point() +
  labs(title = "Frequency vs Impedance for Capacitor")
```

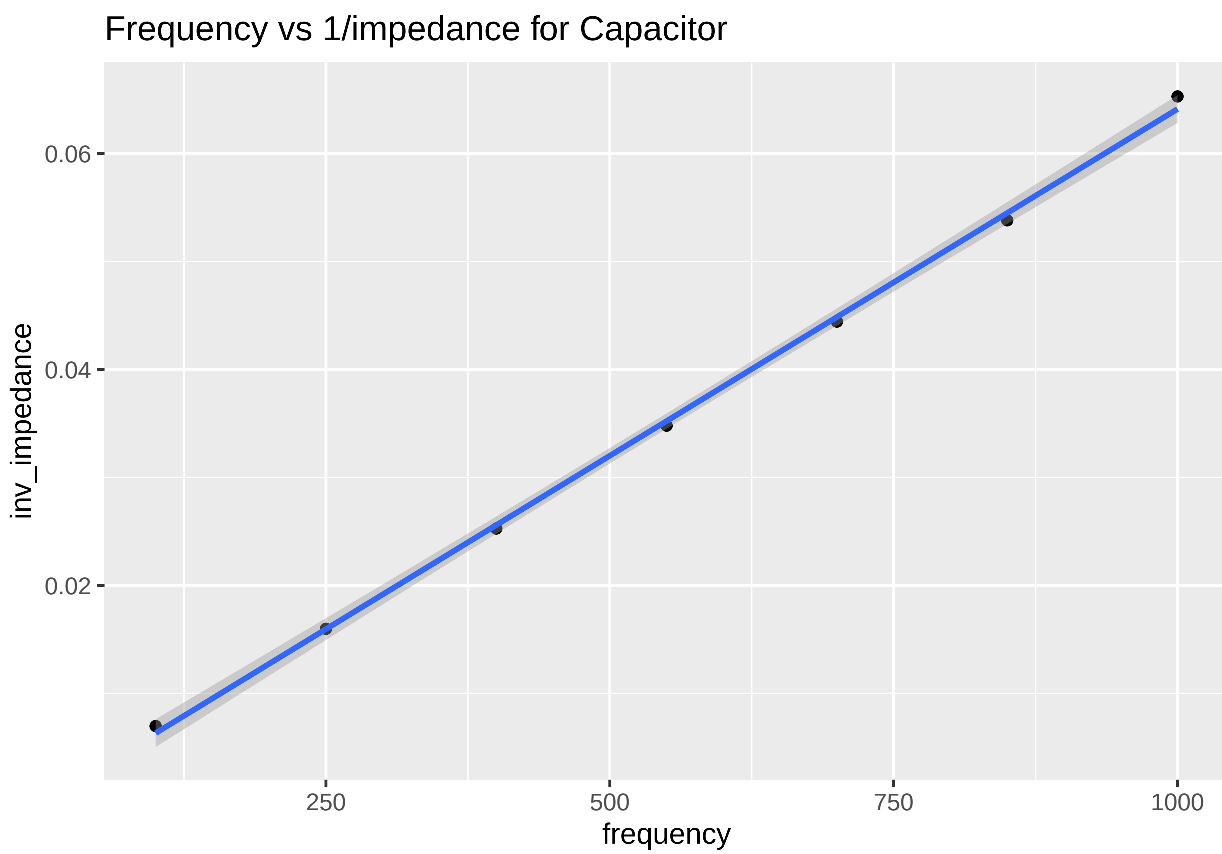


This is nonlinear, so we need to linearize our data. We can do this by doing $\frac{1}{\text{impedance}}$.

```r
linearized_cap <- cap_summary %>%
  mutate(inv_impedance = 1 / impedance)

ggplot(linearized_cap, aes(frequency, inv_impedance)) +
  geom_point() +
  geom_smooth(method = "lm") +
  labs(title = "Frequency vs 1/impedance for Capacitor")
```

```
## `geom_smooth()` using formula = 'y ~ x'
```



We can fit a linear model to the data.

```
summary(lm(linearized_cap$inv_impedance ~ linearized_cap$frequency))
```

```
##
## Call:
## lm(formula = linearized_cap$inv_impedance ~ linearized_cap$frequency)
##
## Residuals:
##          1          2          3          4          5          6          7
##  6.553e-04  3.106e-05 -3.205e-04 -4.268e-04 -4.235e-04 -6.780e-04  1.162e-03
##
## Coefficients:
##                            Estimate Std. Error t value Pr(>|t|)
## (Intercept)              -1.052e-04  5.806e-04  -0.181    0.863
## linearized_cap$frequency  6.422e-05  9.268e-07  69.297 1.19e-08 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.0007356 on 5 degrees of freedom
## Multiple R-squared:  0.999,  Adjusted R-squared:  0.9988
## F-statistic:  4802 on 1 and 5 DF,  p-value: 1.185e-08
```

$$\frac{1}{\text{Impedance}} = \text{Frequency} \cdot 0.00006422$$

The units for the slope are:

$$\frac{1}{\text{impedance} \cdot \text{frequency}} \tag{5}$$
$$[s]^2 \tag{6}$$

$$X_c = \frac{1}{2\pi f C} \tag{7}$$
$$\frac{1}{X_c} = 2\pi f C \tag{8}$$

So the slope is equal to Capacitance $\cdot\, 2\pi$.

```
(2 * pi * 10e-6) / 6.422e-05
```

```
## [1] 0.9783845
```

Yes! There is only a small difference between the calculated and empirical values.

Inductor

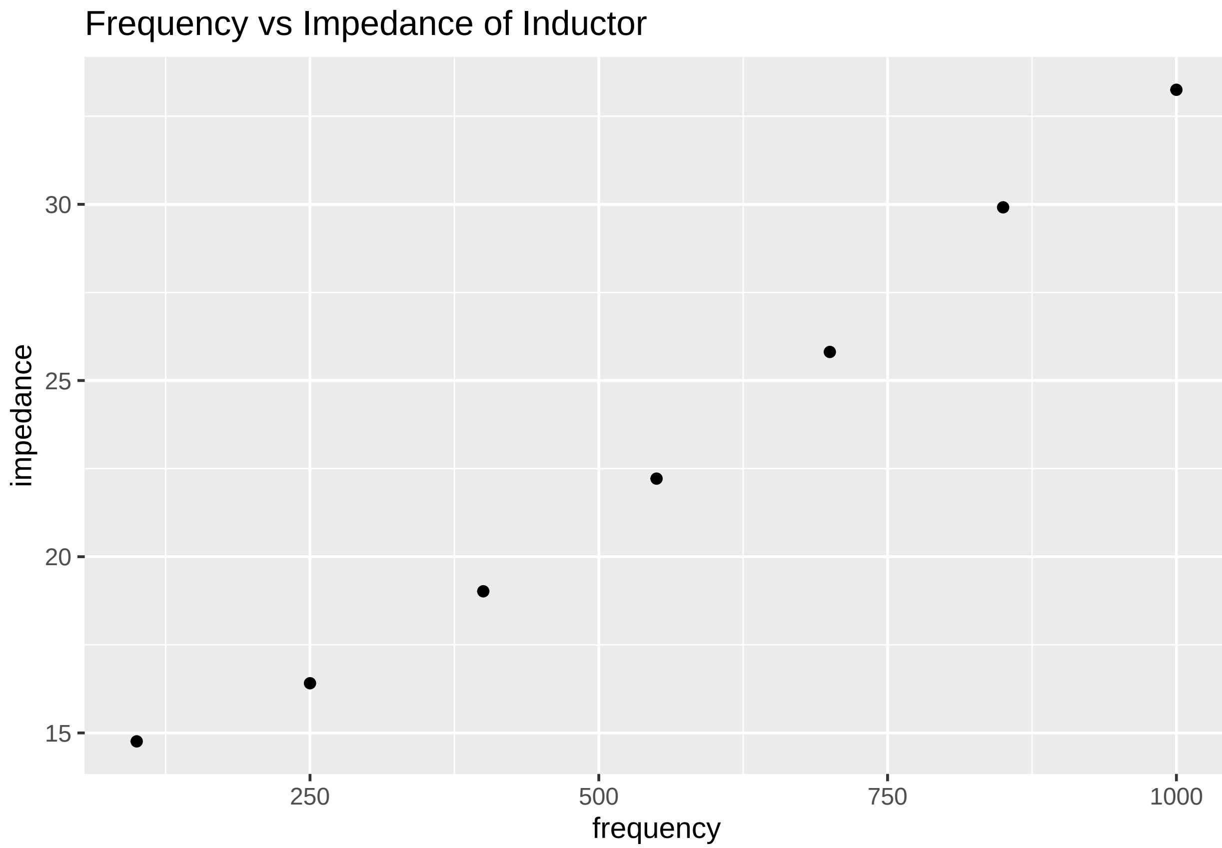
I expect there be less current at higher frequencies since inductors resist changes in current.

There is an inverse relationship between the frequency and current through a inductor.

```
inductor <- read_csv(here("EECS/frequency_vs_current/input/RLC-inductor.csv"),
                     show_col_types = F)
# Splitting the df into many dfs for every 3 columns
ind_dfs <- map(
  seq(1, ncol(inductor), by = 3),
  ~ inductor[, .x:(.x + 2)]
)
# Getting the frequency as a column
ind_df <- map_df(
  1:length(ind_dfs),
  ~ ind_dfs[[.x]] %>%
    mutate(frequency = parse_number(colnames(ind_dfs[[.x]][1]))) %>%
    rename(time = 1, current = 2, potential = 3)
)
# Summarizing
ind_summary <- ind_df %>%
  group_by(frequency) %>%
  summarize(max(abs(potential)) / max(abs(current))) %>%
  rename(impedance = 2)
```

Now we can graph frequency vs impedance for the inductor.

```
ggplot(ind_summary, aes(frequency, impedance)) +
  geom_point() +
  labs(title = "Frequency vs Impedance of Inductor")
```

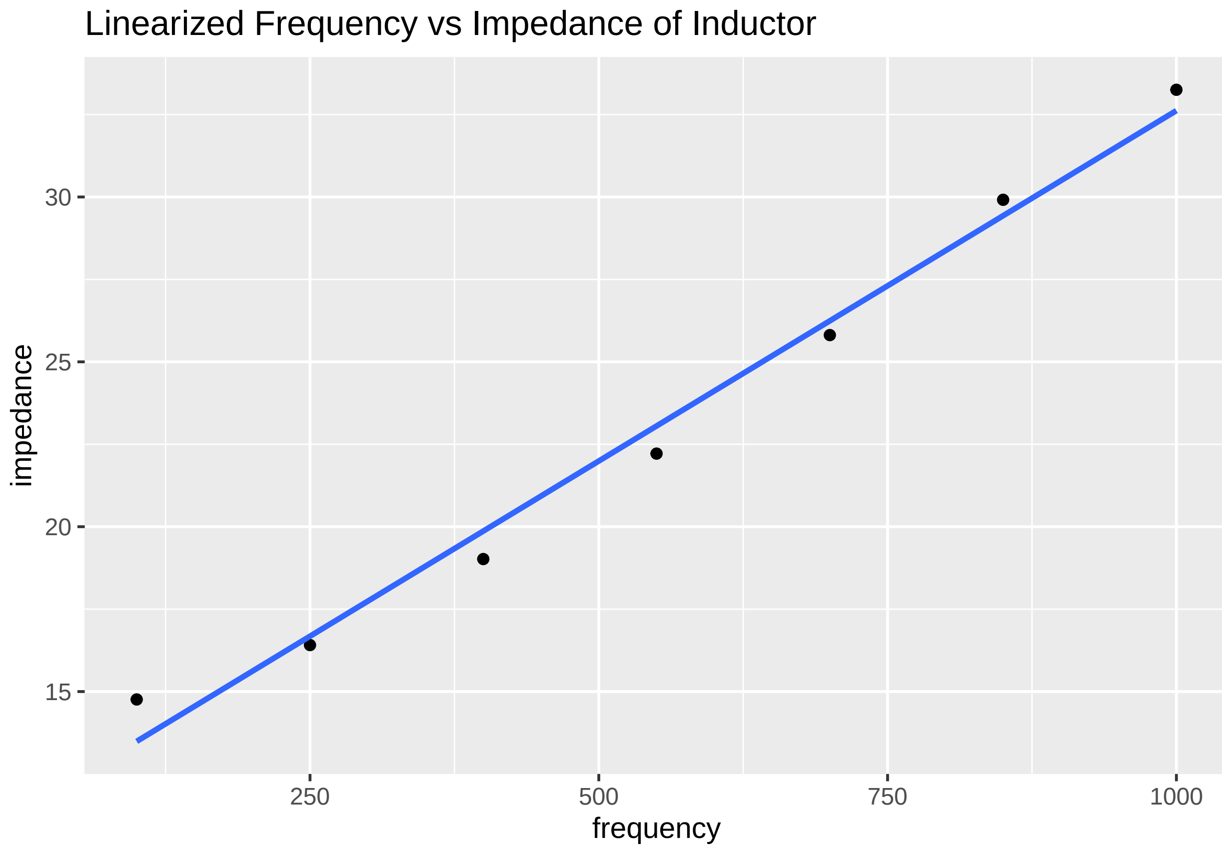


It may appear linear, but it is not!

We need to linearize the data! But I have no idea how to since I thought they were proportional!?!?!

```
ggplot(ind_summary, aes(frequency, impedance)) +
  geom_point() +
  geom_smooth(method = "lm", se = F) +
  labs(title = "Linearized Frequency vs Impedance of Inductor")
```

```
## `geom_smooth()` using formula = 'y ~ x'
```


Linearized Frequency vs Impedance of Inductor
impedance
30
25
20
15
250
500
750
1000
frequency